

Docket No. P8737

PATENT

UNITED STATES APPLICATION FOR LETTERS PATENT

for

METHOD FOR QUADRATURE PHASE
DECODING ALLOWING FOR SKIPPED STATES

By

Philip W. Doberenz

Filed

December 19, 2000

1
2
3
4
5
6
7
8
9
10
11
12
13
14
15
16
17
18
19
20
21
22
23
24
25
26
27
28
29
30
31
32
33
34
35
36
37
38
39
40
41
42
43
44
45
46
47
48
49
50
51
52
53
54
55
56
57
58
59
60
61
62
63
64
65
66
67
68
69
70
71
72
73
74
75
76
77
78
79
80
81
82
83
84
85
86
87
88
89
90
91
92
93
94
95
96
97
98
99
100
101
102
103
104
105
106
107
108
109
110
111
112
113
114
115
116
117
118
119
120
121
122
123
124
125
126
127
128
129
130
131
132
133
134
135
136
137
138
139
140
141
142
143
144
145
146
147
148
149
150
151
152
153
154
155
156
157
158
159
160
161
162
163
164
165
166
167
168
169
170
171
172
173
174
175
176
177
178
179
180
181
182
183
184
185
186
187
188
189
190
191
192
193
194
195
196
197
198
199
200
201
202
203
204
205
206
207
208
209
210
211
212
213
214
215
216
217
218
219
220
221
222
223
224
225
226
227
228
229
230
231
232
233
234
235
236
237
238
239
240
241
242
243
244
245
246
247
248
249
250
251
252
253
254
255
256
257
258
259
260
261
262
263
264
265
266
267
268
269
270
271
272
273
274
275
276
277
278
279
280
281
282
283
284
285
286
287
288
289
290
291
292
293
294
295
296
297
298
299
300
301
302
303
304
305
306
307
308
309
310
311
312
313
314
315
316
317
318
319
320
321
322
323
324
325
326
327
328
329
330
331
332
333
334
335
336
337
338
339
340
341
342
343
344
345
346
347
348
349
350
351
352
353
354
355
356
357
358
359
360
361
362
363
364
365
366
367
368
369
370
371
372
373
374
375
376
377
378
379
380
381
382
383
384
385
386
387
388
389
390
391
392
393
394
395
396
397
398
399
400
401
402
403
404
405
406
407
408
409
410
411
412
413
414
415
416
417
418
419
420
421
422
423
424
425
426
427
428
429
430
431
432
433
434
435
436
437
438
439
440
441
442
443
444
445
446
447
448
449
450
451
452
453
454
455
456
457
458
459
460
461
462
463
464
465
466
467
468
469
470
471
472
473
474
475
476
477
478
479
480
481
482
483
484
485
486
487
488
489
490
491
492
493
494
495
496
497
498
499
500
501
502
503
504
505
506
507
508
509
510
511
512
513
514
515
516
517
518
519
520
521
522
523
524
525
526
527
528
529
530
531
532
533
534
535
536
537
538
539
540
541
542
543
544
545
546
547
548
549
550
551
552
553
554
555
556
557
558
559
560
561
562
563
564
565
566
567
568
569
570
571
572
573
574
575
576
577
578
579
580
581
582
583
584
585
586
587
588
589
590
591
592
593
594
595
596
597
598
599
600
601
602
603
604
605
606
607
608
609
610
611
612
613
614
615
616
617
618
619
620
621
622
623
624
625
626
627
628
629
630
631
632
633
634
635
636
637
638
639
640
641
642
643
644
645
646
647
648
649
650
651
652
653
654
655
656
657
658
659
660
661
662
663
664
665
666
667
668
669
670
671
672
673
674
675
676
677
678
679
680
681
682
683
684
685
686
687
688
689
690
691
692
693
694
695
696
697
698
699
700
701
702
703
704
705
706
707
708
709
710
711
712
713
714
715
716
717
718
719
720
721
722
723
724
725
726
727
728
729
730
731
732
733
734
735
736
737
738
739
740
741
742
743
744
745
746
747
748
749
750
751
752
753
754
755
756
757
758
759
760
761
762
763
764
765
766
767
768
769
770
771
772
773
774
775
776
777
778
779
780
781
782
783
784
785
786
787
788
789
790
791
792
793
794
795
796
797
798
799
800
801
802
803
804
805
806
807
808
809
810
811
812
813
814
815
816
817
818
819
820
821
822
823
824
825
826
827
828
829
830
831
832
833
834
835
836
837
838
839
840
841
842
843
844
845
846
847
848
849
850
851
852
853
854
855
856
857
858
859
860
861
862
863
864
865
866
867
868
869
870
871
872
873
874
875
876
877
878
879
880
881
882
883
884
885
886
887
888
889
890
891
892
893
894
895
896
897
898
899
900
901
902
903
904
905
906
907
908
909
910
911
912
913
914
915
916
917
918
919
920
921
922
923
924
925
926
927
928
929
930
931
932
933
934
935
936
937
938
939
940
941
942
943
944
945
946
947
948
949
950
951
952
953
954
955
956
957
958
959
960
961
962
963
964
965
966
967
968
969
970
971
972
973
974
975
976
977
978
979
980
981
982
983
984
985
986
987
988
989
990
991
992
993
994
995
996
997
998
999
1000
1001
1002
1003
1004
1005
1006
1007
1008
1009
1010
1011
1012
1013
1014
1015
1016
1017
1018
1019
1020
1021
1022
1023
1024
1025
1026
1027
1028
1029
1030
1031
1032
1033
1034
1035
1036
1037
1038
1039
1040
1041
1042
1043
1044
1045
1046
1047
1048
1049
1050
1051
1052
1053
1054
1055
1056
1057
1058
1059
1060
1061
1062
1063
1064
1065
1066
1067
1068
1069
1070
1071
1072
1073
1074
1075
1076
1077
1078
1079
1080
1081
1082
1083
1084
1085
1086
1087
1088
1089
1090
1091
1092
1093
1094
1095
1096
1097
1098
1099
1100
1101
1102
1103
1104
1105
1106
1107
1108
1109
1110
1111
1112
1113
1114
1115
1116
1117
1118
1119
1120
1121
1122
1123
1124
1125
1126
1127
1128
1129
1130
1131
1132
1133
1134
1135
1136
1137
1138
1139
1140
1141
1142
1143
1144
1145
1146
1147
1148
1149
1150
1151
1152
1153
1154
1155
1156
1157
1158
1159
1160
1161
1162
1163
1164
1165
1166
1167
1168
1169
1170
1171
1172
1173
1174
1175
1176
1177
1178
1179
1180
1181
1182
1183
1184
1185
1186
1187
1188
1189
1190
1191
1192
1193
1194
1195
1196
1197
1198
1199
1200
1201
1202
1203
1204
1205
1206
1207
1208
1209
1210
1211
1212
1213
1214
1215
1216
1217
1218
1219
1220
1221
1222
1223
1224
1225
1226
1227
1228
1229
1230
1231
1232
1233
1234
1235
1236
1237
1238
1239
1240
1241
1242
1243
1244
1245
1246
1247
1248
1249
1250
1251
1252
1253
1254
1255
1256
1257
1258
1259
1260
1261
1262
1263
1264
1265
1266
1267
1268
1269
1270
1271
1272
1273
1274
1275
1276
1277
1278
1279
1280
1281
1282
1283
1284
1285
1286
1287
1288
1289
1290
1291
1292
1293
1294
1295
1296
1297
1298
1299
1300
1301
1302
1303
1304
1305
1306
1307
1308
1309
1310
1311
1312
1313
1314
1315
1316
1317
1318
1319
1320
1321
1322
1323
1324
1325
1326
1327
1328
1329
1330
1331
1332
1333
1334
1335
1336
1337
1338
1339
1340
1341
1342
1343
1344
1345
1346
1347
1348
1349
1350
1351
1352
1353
1354
1355
1356
1357
1358
1359
1360
1361
1362
1363
1364
1365
1366
1367
1368
1369
1370
1371
1372
1373
1374
1375
1376
1377
1378
1379
1380
1381
1382
1383
1384
1385
1386
1387
1388
1389
1390
1391
1392
1393
1394
1395
1396
1397
1398
1399
1400
1401
1402
1403
1404
1405
1406
1407
1408
1409
1410
1411
1412
1413
1414
1415
1416
1417
1418
1419
1420
1421
1422
1423
1424
1425
1426
1427
1428
1429
1430
1431
1432
1433
1434
1435
1436
1437
1438
1439
1440
1441
1442
1443
1444
1445
1446
1447
1448
1449
1450
1451
1452
1453
1454
1455
1456
1457
1458
1459
1460
1461
1462
1463
1464
1465
1466
1467
1468
1469
1470
1471
1472
1473
1474
1475
1476
1477
1478
1479
1480
1481
1482
1483
1484
1485
1486
1487
1488
1489
1490
1491
1492
1493
1494
1495
1496
1497
1498
1499
1500
1501
1502
1503
1504
1505
1506
1507
1508
1509
1510
1511
1512
1513
1514
1515
1516
1517
1518
1519
1520
1521
1522
1523
1524
1525
1526
1527
1528
1529
1530
1531
1532
1533
1534
1535
1536
1537
1538
1539
1540
1541
1542
1543
1544
1545
1546
1547
1548
1549
1550
1551
1552
1553
1554
1555
1556
1557
1558
1559
1560
1561
1562
1563
1564
1565
1566
1567
1568
1569
1570
1571
1572
1573
1574
1575
1576
1577
1578
1579
1580
1581
1582
1583
1584
1585
1586
1587
1588
1589
1590
1591
1592
1593
1594
1595
1596
1597
1598
1599
1600
1601
1602
1603
1604
1605
1606
1607
1608
1609
1610
1611
1612
1613
1614
1615
1616
1617
1618
1619
1620
1621
1622
1623
1624
1625
1626
1627
1628
1629
1630
1631
1632
1633
1634
1635
1636
1637
1638
1639
1640
1641
1642
1643
1644
1645
1646
1647
1648
1649
1650
1651
1652
1653
1654
1655
1656
1657
1658
1659
1660
1661
1662
1663
1664
1665
1666
1667
1668
1669
1670
1671
1672
1673
1674
1675
1676
1677
1678
1679
1680
1681
1682
1683
1684
1685
1686
1687
1688
1689
1690
1691
1692
1693
1694
1695
1696
1697
1698
1699
1700
1701
1702
1703
1704
1705
1706
1707
1708
1709
1710
1711
1712
1713
1714
1715
1716
1717
1718
1719
1720
1721
1722
1723
1724
1725
1726
1727
1728
1729
1730
1731
1732
1733
1734
1735
1736
1737
1738
1739
1740
1741
1742
1743
1744
1745
1746
1747
1748
1749
1750
1751
1752
1753
1754
1755
1756
1757
1758
1759
1760
1761
1762
1763
1764
1765
1766
1767
1768
1769
1770
1771
1772
1773
1774
1775
1776
1777
1778
1779
1780
1781
1782
1783
1784
1785
1786
1787
1788
1789
1790
1791
1792
1793
1794
1795
1796
1797
1798
1799
1800
1801
1802
1803
1804
1805
1806
1807
1808
1809
1810
1811
1812
1813
1814
1815
1816
1817
1818
1819
1820
1821
1822
1823
1824
1825
1826
1827
1828
1829
1830
1831
1832
1833
1834
1835
1836
1837
1838
1839
1840
1841
1842
1843
1844
1845
1846
1847
1848
1849
1850
1851
1852
1853
1854
1855
1856
1857
1858
1859
1860
1861
1862
1863
1864
1865
1866
1867
1868
1869
1870
1871
1872
1873
1874
1875
1876
1877
1878
1879
1880
1881
1882
1883
1884
1885
1886
1887
1888
1889
1890
1891
1892
1893
1894
1895
1896
1897
1898
1899
1900
1901
1902
1903
1904
1905
1906
1907
1908
1909
1910
1911
1912
1913
1914
1915
1916
1917
1918
1919
1920
1921
1922
1923
1924
1925
1926
1927
1928
1929
1930
1931
1932
1933
1934
1935
1936
1937
1938
1939
1940
1941
1942
1943
1944
1945
1946
1947
1948
1949
1950
1951
1952
1953
1954
1955
1956
1957
1958
1959
1960
1961
1962
1963
1964
1965
1966
1967
1968
1969
1970
1971
1972
1973
1974
1975
1976
1977
1978
1979
1980
1981
1982
1983
1984
1985
1986
1987
1988
1989
1990
1991
1992
1993
1994
1995
1996
1997
1998
1999
2000
2001
2002
2003
2004
2005
2006
2007
2008
2009
2010
2011
2012
2013
2014
2015
2016
2017
2018
2019
2020
2021
2022
2023
2024
2025
2026
2027
2028
2029
2030
2031
2032
2033
2034
2035
2036
2037
2038
2039
2040
2041
2042
2043
2044
2045
2046
2047
2048
2049
2050
2051
2052
2053
2054
2055
2056
2057
2058
2059
2060
2061
2062
2063
2064
2065
2066
2067
2068
2069
2070
2071
2072
2073
2074
2075
2076
2077
2078
2079
2080
2081
2082
2083
2084
2085
2086
2087
2088
2089
2090
2091
2092
2093
2094
2095
2096
2097
2098
2099
2100
2101
2102
2103
2104
2105
2106
2107
2108
2109
2110
2111
2112
2113
2114
2115
2116
2117
2118
2119
2120
2121
2122
2123
2124
2125
2126
2127
2128
2129
2130
2131
2132
2133
2134
2135
2136
2137
2138
2139
2140
2141
2142
2143
2144
2145
2146
2147
2148
2149
2150
2151
2152
2153
2154
2155
2156
2157
2158
2159
2160
2161
2162
2163
2164
2165
2166
2167
2168
2169
2170
2171
2172
2173
2174
2175
2176
2177
2178
2179
2180
2181
2182
2183
2184
2185

METHOD FOR QUADRATURE PHASE DECODING ALLOWING FOR SKIPPED STATES

5

BACKGROUND

1. Field

10 This invention relates to decoding methods for quadrature signal devices, more particularly to quadrature phase decoding methods.

2. Background

15 Quadrature phase decoding may be used to detect movement of an object. In a typical configuration, a decoder wheel is used, inset such that there are slots around the wheel. A phototransistor with two outputs A and B is positioned such that the A and B photosensors are aligned with the slots and offset ninety degrees. This results in the A and B outputs, typically square waves, being ninety degrees out of phase with each other. The two digital outputs then create four possible outputs, hence the name quadrature. An example of two, ninety degree out of phase, square waves is shown in Figure 1.

20 In most motion detection applications of quadrature decoding, there are two decoder wheels and two sets of photosensors and phototransistors. Each set tracks on axis, having outputs XA, XB, YA and YB. Each set of outputs may be used in a state machine to determine an output signal. The output signals from both sets are compared to the previous state and then used to determine motion and direction. An example of a typical state machine used for one set is shown in Figure 2. A lookup table for this state diagram is shown below.

Present State	Last State	Output	Present State	Last State	Output
00	00	0	10	00	-1
00	01	-1	10	01	0
00	10	1	10	10	0
00	11	0	10	11	1
01	00	1	11	00	0
01	01	0	11	01	1
01	10	0	11	10	-1
01	11	-1	11	11	0

25

With this method, every state must be sampled. If a state is skipped, the last state and present state information will not allow direction to be determined. If the object moves quickly, the quadrature frequency will increase. The quadrature frequency is the frequency at which the states change. Therefore, the sampling frequency must be set high enough to allow

for fast movements. If the sampling rate is not high enough, a state will be skipped and the movement information will be lost, resulting in inaccurate tracking.

A common use for this type of movement detection and decoding is in user pointing devices, such as a computer mouse. The computer mouse may be connected to the host computer by a wire or by some sort of wireless connection, such as infrared. The output of the mouse to the host computer depends upon the results of the state changes and the corresponding outputs. This information allows the computer to depict the mouse movement on the screen with the cursor. If the data is inaccurate because of skipped states, the mouse will not be very useful. Similarly, having a high sampling rate for the mouse ties up computer resources. A more effective method for quadrature decoding may result in a lower sampling rate without loss of movement data.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention may be best understood by reading the disclosure with reference to the drawings, wherein:

Figure 1 shows a prior art example of a quadrature phase diagram.

Figure 2 shows an example of a prior art quadrature state diagram.

Figures 3a and 3b show examples of positive and negative state diagrams, respectively, in accordance with the invention.

Figure 4 shows a flowchart of one embodiment of a method to decode quadrature signals in accordance with the invention.

Figure 5 shows one embodiment of a user pointing device in accordance with the invention.

DETAILED DESCRIPTION OF THE EMBODIMENTS

As mentioned previously, Figure 1 shows a phase diagram for two outputs of a quadrature decoder pair. The output signals A and B are ninety degrees out of phase. This allows the system to detect the movement of a decoder wheel, and the corresponding movement of an object. A corresponding state diagram for these two signals is shown in Figure 2.

In operation, the state machine may provide a way to track the movement of an object. For example, the object starts in a resting position, at state 00. As it moves, the square waves of the outputs A and B change as the decoder wheel spins. The movement may be from state

00 to state 10 to state 11, for example. If this state machine is for the X axis, the output for the X axis would be a 1 for the state change from 00 to 10 and another 1 for the state change 10 to 11. Typically, the current processes use the last state and the present state to determine direction of the move.

5 To determine movement and direction, these results are typically summed up and sent to the host computer. For example, assume that samples are taken every 200 microseconds, and an output is transmitted to the host computer every 10 milliseconds. In this example, 50 samples are taken during each period between transmissions. If the positive direction for the X axis state machine is to the right, and the positive direction for the Y axis state machine is up, a resulting output may be X +4, and Y +2. There may have been some direction reversals in between the two transmissions, but in general, the net movement was in a positive direction for both X and Y.

15 Each sample taken may or may not produce a new state. If the mouse is at rest between transmissions, there will be no state changes, and therefore there will be no outputs to sum. As the states change, for example, from 00 to 01 to 11, each would result in a 1, and the sum for that axis would be a net change of +2. In this manner, the state machine allows the controller or processor in the moving object to communicate movement to a host computer.

20 However, in the current state of the art a problem with regard to the sample rate occurs as the movement speed of the object increases. If the change from 00 to 10 to 11 accelerates, less time is spent in each state. The time spent in each state may become so short that the state is not sampled. This would result in the last state being 00 and the present state being 11. Since a state was skipped, the current implementations of state machines cannot tell if the object changed states by going in one direction, resulting in the sequence 00, 10, 11, or in the opposite direction, resulting in the sequence 00, 01, 11. Without last state data that 25 is from a state sequential with the present state, the direction data is inaccurate or lost.

30 An embodiment of a set of state machines that can account for skipped states is shown in Figures 3a and 3b. As mentioned above, current implementations typically store the last state and the present state only. In this embodiment, both the last state and the direction of the last sample are used. The direction of the last sample may be determined by determining the direction between the last sample and the previous sample. A change in direction will typically not happen so quickly that a state will be skipped before a valid direction change can be determined.

In this embodiment the direction corresponding to changes from 00 to 10 to 11 to 01 to 00 will be defined as the positive direction. The direction corresponding to changes from 00 to 01 to 11 to 10 to 00 will be defined as the negative direction. Using the direction of the last sample, referred to here as the last direction, the correct lookup table can be selected. If the last state, last direction and the present state indicate a skipped state, the table provides a different output. Figure 3a shows one embodiment of a state diagram for the positive direction, for example. If a state is skipped, such as going from 00 to 11, the resulting output would be a +2, identifying a skipped state. This takes into account the change from 00 to 01, which should have resulted in a 1, and the change from 01 to 11, which should have resulted in another 1. The sum of the outputs of the two state changes is 2. The output tables are shown below.

Positive Direction

Present State	Last State	Output	Present State	Last State	Output
00	00	0	10	00	-1
00	01	-1	10	01	2
00	10	1	10	10	0
00	11	2	10	11	1
01	00	1	11	00	2
01	01	0	11	01	1
01	10	2	11	10	-1
01	11	-1	11	11	0

Negative Direction

Present State	Last State	Output	Present State	Last State	Output
00	00	0	10	00	-1
00	01	-1	10	01	-2
00	10	1	10	10	0
00	11	-2	10	11	1
01	00	1	11	00	-2
01	01	0	11	01	1
01	10	-2	11	10	-1
01	11	-1	11	11	0

Using these tables it is possible to identify a result where a state was skipped. When used in combination with the direction, it is possible to determine which state was skipped.

Allowance of skipped states relaxes the sampling requirement. Lower sampling rates can be used for the same current object movement speed.

In the example of a user pointing device, such as a mouse, a lower sampling rate could be used for the same current mouse speed. Alternatively, the same sampling rate could be used and the maximum possible mouse speed could be increased, or a mix of the two. The mouse could have a faster speed without a jerky cursor movement, as would be the case using current approaches. Other devices that may use quadrature decoding include measuring devices, such as digital calipers.

The improved capability, whether it impact sampling rates or object speeds, may be provided to users in the form of software. A computer readable medium, such as a diskette, CD-ROM, or digital signal processor (DSP) image file would contain software code. The software code, when executed, would result in use of a method to obtain samples of the decoder photosensor outputs and use those samples to determine the outputs based upon the present state, last state and last sample direction.

A flowchart of one embodiment of such a method is shown in Figure 4. The last state is retrieved at 10 and the current sample is obtained at 12. These could be performed sequentially or in parallel, depending upon the desires of the designer. In addition, the direction of the last sample, referred to here as the last direction, is determined at 14. The last direction could be determined previously and stored.

For example, the current sample and the last sample will become the last sample and the previous when a new sample is obtained. The method could determine the direction between these two variables prior to obtaining the new sample. The variable stored would be the last direction. When the new sample is obtained, the last sample and the last direction variables would be retrieved from wherever they are stored and used to determine the output of the state machine.

Alternatively, a first sample is taken. The value of the first sample will become the last state, and the sign of the sample will become the last direction. When a second sample is taken, the second sample is obtained, from which is determined the current state. These are used in determining the necessary output. In either case, as well as other embodiments, the last state and last direction will be determined in some manner using a first sample, and the current state will be determined using a second sample.

As discussed above, this approach can be used for tracking of objects using quadrature detection. One example given was that of a user pointing device, such as a mouse. In this example, the computer readable medium including the software code would more than likely

be contained in a mouse driver file. One embodiment of a mouse capable of using such a driver in accordance with the invention is shown in Figure 5.

The mouse 20 has a rolling ball 22. The rolling ball 22 is typically restrained from falling away from the mouse case by a ring 24. Underneath or otherwise adjacent the ring 24 are decoder wheels 26a and 26b. In this example, decoder wheel 26a is used for the X axis movement and decoder wheel 26b is used for the Y axis movement. Photosensors XA, XB, YA and YB provide input to the state machine 30, which is more than likely contained on a controller, processor or other integrated circuit. The state machine 30 and the memory 28 may be co-located on the same integrated circuit. The memory 28 may be any type of storage, including a memory register or a RAM array.

In one embodiment, the processor or controller stores the last state and direction, determined from the last sample. The state machine/controller 30 receives the inputs XA, XB, YA and YB as the current sample. It then accesses the memory to retrieve the last sample and the last direction. These inputs are then used to determine the appropriate output 32, which is sent to the host computer. Again, using the last sample direction, however determined, allows the sampling rate to be decreased, or the maximum speed of the object to be increased.

In this manner, a skipped state may be detected and adjusted for. This feature is also extensible to handling more than one skipped state. The velocity of the mouse, for example, relates to the frequency of the quadrature signals and may be very fast. The acceleration will actually be much slower. A person can only accelerate a hand so quickly. In addition, direction changes are also relatively slow. Even in these conditions, the skipped state quadrature decoder shown above overlaps enough to get accurate information when it is moving one state at a time in the direction that the other table is handling.

Since the acceleration is relatively slow, it is more like that when a state is skipped, the device is still moving in one direction. The decoding of skipped states can be extended to allow choosing of different tables if more states are skipped without inaccurate or lost data. This is shown by the table below.

State Change	-3	-2	-1	0	+1	+2	+3
Standard Table (prior art)	X	X	-1	0	+1	X	X
A. Positive table 1 skipped state			-1 Table B	0 Keep	+1 Keep	+2 Table C	
B. Negative table 1 skipped state		-2 Table D	-1 Keep	0 Keep	+1 Table A		
C. Positive table 2 skipped states				0 Table A	+1 Keep	+2 Keep	+3
D. Negative table 2 skipped states	-3	-2 Keep	-1 Keep	0 Table B			

Indications of "Table B," for example, indicate that the output should be acquired from the values of Table B. The indicator "Keep" direct the output to be obtained from the current table.

Thus, although there has been described to this point a particular embodiment for a method and apparatus for improved quadrature detection and decoding, it is not intended that such specific references be considered as limitations upon the scope of this invention except in-so-far as set forth in the following claims.